

Low vs. high concentration of levobupivacaine for post-operative epidural analgesia: influence of mode of delivery

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Background: Although the use of continuous epidural infusion (CEI) and patient-controlled epidural analgesia (PCEA) has become commonplace in pain management, there is still controversy regarding the relative effects of mass, volume and concentration of the local anaesthetic. This prospective study evaluated the influence of two concentrations of levobupivacaine on the quality of analgesia in two modes of delivery after lower abdominal surgery.

Methods: Eighty-two patients were randomly assigned to four groups to receive combined low thoracic epidural analgesia and general anaesthesia followed by post-operative CEI or PCEA using 1.5 or 5 mg/ml levobupivacaine (15 mg/h in CEI and bolus 5 mg, lockout 20 min in PCEA). Sensory block, pain scores, levobupivacaine and rescue morphine consumption, motor blockade, haemodynamics, side-effects and patient satisfaction were registered within 48 h.

Results: The four groups were similar with regard to demographics, quality of analgesia, morphine consumption and satisfaction rate. No difference in the quality of analgesia was observed for the two modes of delivery with regard to the

concentration of levobupivacaine, but the consumption of the local anaesthetic was higher in the CEI groups. The Bromage scores in the PCEA groups were reduced to zero for all except one patient, whereas eight patients presented scores of one or more in the CEI population.

Conclusion: Levobupivacaine in thoracic epidurals provides an equal quality of post-operative analgesia in low and high volume independent of the delivery mode, i.e. CEI or PCEA. This is in accordance with the assumption that the total dose of the local anaesthetic determines the quality of analgesia.

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BOTH continuous epidural infusion (CEI) of local anaesthetics and patient-controlled epidural analgesia (PCEA) have been shown to be safe and effective in the management of post-operative pain (1–3). Although the use of such analgesic modalities has become commonplace, there is still controversy with regard to the relative effects of the mass, volume and concentration of local anaesthetic solution in both delivery modes. Clinical studies have shown conflicting results, probably because of the limited consideration of the total dose (4–8). Bromage (9) found that it was the total local anaesthetic dose, and not the total volume, that determined the spread and quality of analgesia. This has been confirmed by others, after both lumbar and mid-thoracic epidural administration (10, 11). For CEI, Darnedde et al. (12, 13) have demonstrated

recently that a high concentration/low volume of local anaesthetic provides an equal quality of post-operative analgesia as a low-concentration/high-volume infusion and induces less motor blockade and haemodynamic repercussions. In PCEA, a few studies have evaluated the influence of the volume and concentration of local anaesthetic for abdominal surgery, but the results are conflicting (3, 14–17). The question arises as to whether the mode of delivery influences the quality of post-operative analgesia, and whether the volume and concentration of the local anaesthetic have a further impact.

Therefore, we designed this prospective, blind, randomised study to compare CEI vs. PCEA using two concentrations of opioid-free levobupivacaine. The goals of this study were to investigate the impact of the dose, volume and concentration of

the local anaesthetic in the two modes of delivery on the quality of analgesia and the incidence of side-effects after lower abdominal surgery.

Materials and methods

Following approval by the Ethics Committee, written informed consent was obtained from 90 consecutive ASA physical status I-III patients undergoing elective lower abdominal surgery. Patients were included if they were 18–75 years of age, were able to read and understand French and to use the PCEA device, had normal mental health and had been hospitalised for elective surgery. Exclusion criteria were sepsis, allergy to amide-type local anaesthetics or morphine and coagulopathy. Patients were also excluded if they received chronic pain therapy. At the time of the pre-operative visit, patients were familiarised with a 10-cm visual analogue scale (VAS) device for pain (0, no pain at all; 10, worst imaginable pain) and nausea (0, no nausea at all; 10, worst imaginable nausea) intensity assessment (18).

Patients were pre-medicated with midazolam before the induction of anaesthesia. In the operating room, after the infusion of 500 ml of Ringer's solution via an intravenous cannula, a 20-gauge epidural catheter was inserted through an 18-gauge Tuohy needle into the epidural space at low thoracic levels. The epidural catheter was directed cephalad for a distance of 4 cm and fixed to the back of the patient. As soon as the patient was in a supine position, a test dose of 3 ml of levobupivacaine (5 mg/ml) (Chirocaine, Abbott, Louvain-la-Neuve, Belgium) was injected through the catheter.

Anaesthesia was maintained with sevoflurane in 50% oxygen in air or nitrous oxide, combined with sufentanil and non-depolarising muscle relaxant. Three to six millilitres of 5 mg/ml levobupivacaine were injected through the epidural catheter for the surgical procedure. If surgery lasted longer than 2 h, patients received a re-injection of half of the volume of the local anaesthetic using the same concentration. After completion of the operation and tracheal extubation, patients were transferred to the Post-Anaesthesia Care Unit (PACU) where they remained under constant observation for approximately 4 h. In a random fashion, using a computer-generated random number table, the patients received either CEI with 5 mg/ml levobupivacaine at 3 ml/h (group 1, $n = 24$) or 1.5 mg/ml levobupivacaine at 10 ml/h (group 2, $n = 22$), or PCEA levobupivacaine at 1.5 mg/ml as a 3.3-ml bolus on

demand, with a lockout interval of 20 min (group 3, $n = 22$), or 5 mg/ml as a 1-ml bolus on demand, with a similar lockout interval (group 4, $n = 22$) without background infusion. The same pump (Abbott *aim plus*, Abbott Laboratories, North Chicago, IL) was used for all patients. Devices were directly connected on arrival in the PACU and epidural infusion was started, independent of the VAS score. Patients were blind to the drug concentration administered epidurally. No extra bolus injection or change in the infusion rate was allowed. For further post-operative pain relief patients received six-hourly intravenous propacetamol (2 g) and ketorolac (60 mg) within 24 h, unless there were medical or surgical contraindications. Rescue medication via morphine was provided via subcutaneous injections after evaluation of the VAS every 4 h. The consumption of analgesic drugs was recorded during the 48-h study period. After 48 h, the infusion of levobupivacaine was discontinued and alternative analgesia was provided.

On arrival in the PACU, patients were asked to rate their pain experience on the VAS device. This process was repeated every 2 h for the first 4 h. When the patient was moved to the general surgical ward, it was continued every 4 h for 48 h. Only rest pain was assessed, defined as the pain experienced at this time point by the patient whilst lying in bed. The pain threshold was set at 3 cm on the VAS (19). Nausea intensity was evaluated at the same time interval using a VAS device, and vomiting was recorded as either present or absent by direct observation or by spontaneous complaint from the patient. Nausea was defined as a patient's rating score of more than 4 cm on the VAS (18). Rescue medications given for nausea and/or vomiting were recorded. The cephalad level of sensory block was evaluated by loss of sensation to cold using ether swabs at the same time. If the levels of sensory block on the right and left sides were different, the most cephalad was recorded. In the case of sensory block exceeding Th4, epidural infusion was stopped until the return of an upper level below this limit. Motor blockade was assessed according to a modified Bromage scale (0, no motor block; I, inability to raise extended legs; II, inability to flex knees; III, inability to flex ankle joints) (20). Nurses, who were blind to the type of epidural solution and mode of delivery, collected the data.

Hypotension was defined as a 30% decrease in systolic blood pressure compared with baseline, bradycardia was defined as a heart rate of less than 50 beats/min, and bradypnoea was defined

as a respiratory rate of less than 10 breaths/min. Baseline values were measured at the time of the pre-operative visit. Sedation was recorded on a four-point scale (0, no signs of sedation; 1, mild sedation; 2, moderate sedation; 3, severe sedation). The patients were questioned every 4 h to determine the presence of early numbness or any warning signs of local anaesthetic systemic toxicity, such as circumoral numbness and tinnitus.

On days 1 and 2, the patients were visited by a pain nurse from the Acute Pain Service who interviewed them about their satisfaction with post-operative analgesia. The quality of pain management was judged by the patient on a four-point scale (1, very dissatisfied; 2, dissatisfied; 3, satisfied; 4, very satisfied).

Statistical analysis

Results were expressed as the means \pm standard deviation for quantitative variables, the median for the upper level of dermatomal sensory blockade and the frequency for categorical findings. Time-related VAS measurements were summarised using a series of pain indicators described elsewhere (21): *AUC*, area under the VAS-time curve (cm^2); *VAS_{max}*, peak of VAS (cm); *VAS_{mean}*, mean VAS (cm); *PVAS* > 3, the persistence of VAS over 3 cm, i.e. the time period during which VAS was above the critical threshold (h). The comparison of mean values was performed using Student's *t*-test, whereas proportions were compared by the classical chi-squared test. The general linear model (GLM) was used to analyse repeated measures of continuous data. The GLM tests two null hypotheses as follows: 1, time has no effect on the variable, which means that the variable mean of the combined groups does not vary over time; 2, the time patterns are equal between the two groups, which means that the difference between the mean of each group is the same at every time point. The Bonferroni test, based on Student's *t*-statistic, was used for *post hoc* testing. Upper dermatomal levels of sensory block were compared using the Mann-Whitney *U*-test. The number of patients included in the study was based on our previous results and on a power calculation assuming a 20% difference in VAS pain scores with $\alpha = 0.05$ and $\beta = 0.20$ (12, 13). All statistical calculations were carried out using the SAS package (SAS Institute, Cary, NC; version 6.12) and always using all data available. Results were considered to be significant at the 5% critical level ($P < 0.05$).

Results

Eight patients were excluded as a result of protocol deviation (one patient in the 1.5 mg/ml CEI group), lack of data recording (two patients in the 1.5 mg/ml CEI group, three patients in the 1.5 mg/ml PCEA group and one patient in the 5 mg/ml PCEA group) or accidental removal of the catheter (one patient in the 5 mg/ml CEI group). Eighty-two patients with complete case report forms were included in the study (20 in the 1.5 mg/ml and 21 in the 5 mg/ml CEI groups, 21 in the 1.5 mg/ml and 20 in the 5 mg/ml PCEA groups). In these patients, epidural catheters were functioning until the end of the observation period. The patient characteristics and distribution according to the type of surgery are displayed in Table 1. The demographic data, baseline recordings and type of surgery were similar in the four groups. Specifically, there was no difference in age range between the four groups.

The level of insertion of the epidural catheter was low thoracic (Th8–Th11). In the 5 mg/ml group, the catheters were inserted slightly lower (Th10–L1). No cases of accidental dural puncture occurred. At the time of surgery, patients received the same amount of intravenous sufentanil ($25 \pm 10 \mu\text{g}$ in the 1.5 mg/ml CEI group, $20 \pm 8 \mu\text{g}$ in the 5 mg/ml CEI group, $23 \pm 9 \mu\text{g}$ in the 1.5 mg/ml PCEA group and $23 \pm 7 \mu\text{g}$ in the 5 mg/ml PCEA group; $P = 0.38$). There was no difference between the groups in the amount of peri-operative epidural levobupivacaine used ($53 \pm 21 \text{ mg}$ in the 1.5 mg/ml CEI group, $59 \pm 22 \text{ mg}$ in the 5 mg/ml CEI group, $51 \pm 16 \text{ mg}$ in the 1.5 mg/ml PCEA group and $53 \pm 14 \mu\text{g}$ in the 5 mg/ml PCEA group; $P = 0.50$). The quality of anaesthesia was judged to be adequate in all patients by the attending anaesthesiologist.

The median upper level of sensory blockade at the different time points after surgery is illustrated in Fig. 1. In the 1.5 mg/ml groups, sensory block was more extensive in the CEI group (Th7) than in the PCEA group (Th8–Th9) ($P < 0.01$). For the high-concentration solutions, sensory block was higher in the PCEA group during the first 24 h (Th7 vs. Th9 in the CEI group; $P < 0.01$). No upper level above Th4 was observed in any patient.

Figure 2 shows the VAS pain scores during the first 48 post-operative hours in the four groups. VAS scores for pain at rest were higher in the PCEA groups ($P = 0.019$; GLM statistics). The values of the pain indicators are displayed in Table 2. *AUC*, *VAS_{max}*, *VAS_{mean}* and *PVAS* > 3

Table 1

Demography and type of surgery in the four groups. Concentration (1.5 and 5 mg/ml) refers to levobupivacaine. Results are presented as the mean \pm standard deviation or frequency.					
Variable	1.5 mg/ml CEI (n = 20)	1.5 mg/ml PCEA (n = 21)	5 mg/ml CEI (n = 21)	5 mg/ml PCEA (n = 20)	Total (n = 82)
Gender (male/female)	6/14	7/14	8/13	9/11	30/52
Age (years) (range)	59.5 \pm 11.2 (46–74)	54.5 \pm 11.1 (35–72)	60.2 \pm 14.5 (34–75)	53.8 \pm 13.1 (27–73)	57.0 \pm 12.7
Weight (kg)	74.0 \pm 13.6	73.0 \pm 14.4	74.7 \pm 18.9	75.0 \pm 15.7	74.1 \pm 15.5
Height (cm)	167 \pm 7.82	167 \pm 9.88	165 \pm 7.66	168 \pm 9.17	167 \pm 8.60
BMI (kg/m ²)	26.7 \pm 4.54	26.0 \pm 3.99	27.6 \pm 7.12	26.6 \pm 4.60	26.7 \pm 5.13
Type of surgery					
Visceral	9	5	7	6	27 (33%)
Gynaecological	10	12	10	10	42 (51%)
Urological	1	4	4	4	13 (16%)
ASA					
I	3	4	6	2	15 (18%)
II	15	13	12	16	56 (68%)
III	2	4	3	2	11 (14%)
					0.66

ASA, American Society of Anesthesiologists; BMI, body mass index; CEI, continuous epidural infusion; PCEA, patient-controlled epidural analgesia.

were significantly higher in the PCEA groups. No relationship was found between the type of surgery and the efficacy of pain relief.

Post-operative analgesic consumption is displayed in Table 2. The total amount of levobupivacaine consumed after 48 h was higher in the two CEI groups (720.0 \pm 0.0 mg) than in the PCEA groups (170 \pm 103 mg in the 1.5 mg/ml group and 182 \pm 110 mg in the 5 mg/ml group; $P < 0.001$). In the PCEA groups, levobupivacaine consumption decreased during the second post-operative 24 h (Table 2). Propacetamol was given to all patients and ketorolac was administered to 20 (100%) patients in the 1.5 mg/ml CEI group, 18 (85.7%) patients in the 5 mg/ml CEI group, 17 (81.0%) patients in the 1.5 mg/ml PCEA group and 15 (75.0%) patients in the 5 mg/ml PCEA group ($P = 0.14$). The variation of non-steroidal anti-inflammatory drug (NSAID) administration occurred as a result of medical contraindications. A significant difference was observed between the two 1.5 mg/ml groups ($P = 0.039$). Rescue analgesia, represented by morphine consumption, was similar in the four groups ($P = 0.21$). No difference could be found between the two groups with regard to nausea and vomiting ($P = 0.10$). No life-threatening respiratory events associated with opioid administration were reported during the study period.

The Bromage score was decreased to zero within the 48-h period for all but one patient in the PCEA groups. In the 5 mg/ml CEI group, eight patients presented a motor blockade score of \geq I between 8 and 40 h. In the 1.5 mg/ml PCEA group, one patient presented a Bromage score of I and another a score of II during the 48-h study period (Table 2).

Figure 3 displays the evolution of the blood pressure and heart rate. There was a significant difference in haemodynamic variables: systolic and diastolic blood pressures were lower in the 1.5 mg/ml CEI group compared with the 1.5 mg/ml PCEA group ($P = 0.036$). No difference was observed in the 5 mg/ml groups. GLM statistics showed a highly significant time effect on the variables ($P < 0.001$), a significant time pattern ($P < 0.001$) and significantly different overall means of the groups ($P < 0.001$). No vasoconstrictors or atropine were given for the treatment of hypotension or bradycardia during the study period. No sedation, respiratory depression or pruritus was observed in any patient. No patient complained of warning signs of local anaesthetic systemic toxicity. All patients in the four groups were satisfied or very

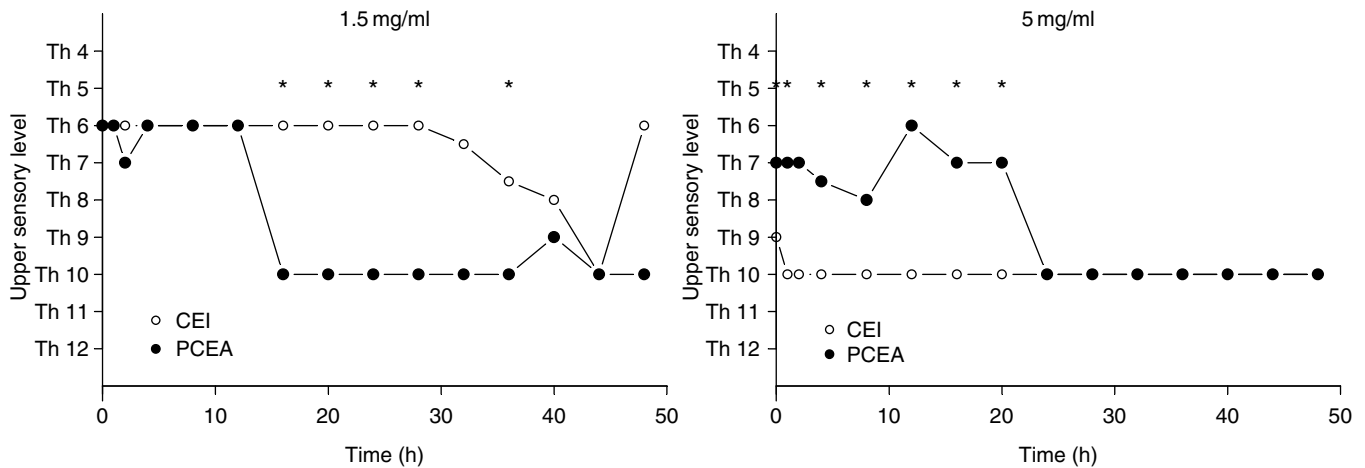


Fig. 1. Evolution of the median upper sensory dermatomal level in the four groups of patients during the 48-h study period. Concentration (1.5 and 5 mg/ml) refers to levobupivacaine. CEI, continuous epidural infusion; PCEA, patient-controlled epidural analgesia; Th, thoracic. Sensory block was more extensive in the 1.5 mg/ml CEI and 5 mg/ml PCEA groups ($P < 0.01$; general linear model statistics). * $P < 0.05$ (Mann-Whitney U-test).

satisfied with the quality of pain management (Table 2).

Discussion

The results of the present study show that thoracic CEI using opioid-free levobupivacaine provides an equal quality of post-operative analgesia as PCEA, without background infusion, after lower abdominal surgery. The VAS pain scores were very low in both groups, i.e. below 3 cm during the study period. Our data support the view that altering the concentration and volume of levobupivacaine

results in the same quality of analgesia after CEI or PCEA administration. Minimal side-effects were observed with better haemodynamic stability in the large-concentration/small-volume groups than in the small-concentration/large-volume groups. All groups achieved similar levels of patient satisfaction. However, the total amount of levobupivacaine infused was higher in the CEI groups (720 ± 0 mg) than in the PCEA groups (170 ± 103 mg in the 1.5 mg/ml group and 182 ± 110 mg in the 5 mg/ml group). The dose-sparing effect of PCEA has been demonstrated previously (3, 22).

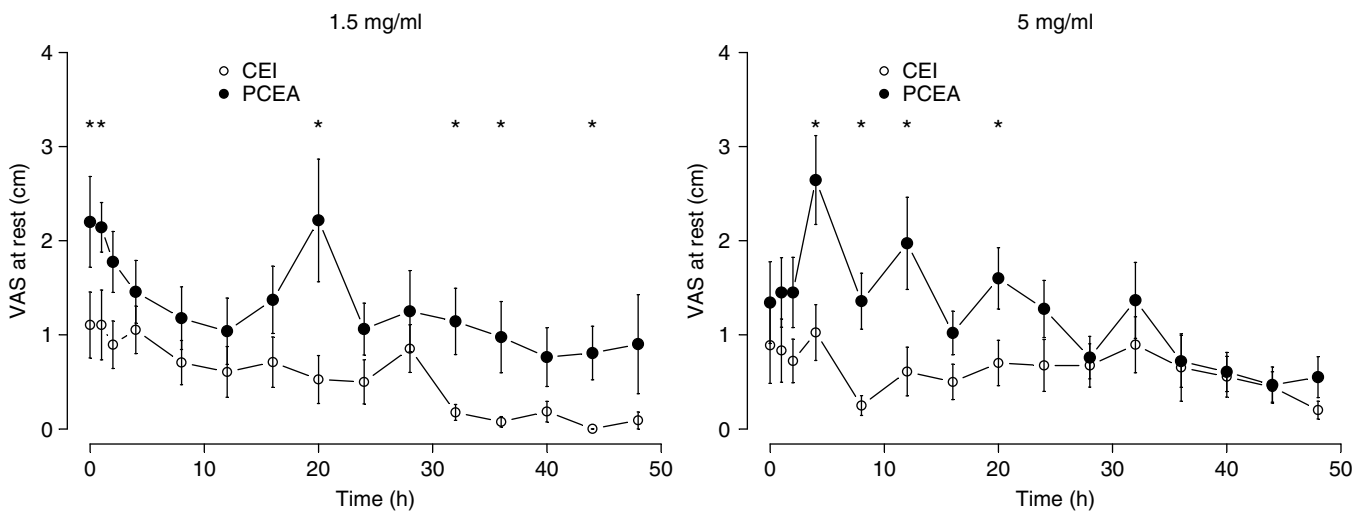


Fig. 2. Evolution of the mean visual analogue scale (VAS) scores at rest, expressed in centimeters (cm), in the four groups of patients during the 48-h study period. Concentration (1.5 and 5 mg/ml) refers to levobupivacaine. CEI, continuous epidural infusion; PCEA, patient-controlled epidural analgesia. Errors bars indicate standard deviation. VAS pain scores were higher in the PCEA groups ($P = 0.019$; general linear model statistics). * $P < 0.05$ (Student's *t*-test).

Table 2

Pain indicators, post-operative analgesics and anti-emetic consumption in the four groups (mean \pm standard deviation or frequency). Concentration (1.5 and 5 mg/ml) refers to levobupivacaine.

Variable	1.5 mg/ml CEI (n = 20)	1.5 mg/ml PCEA (n = 21)	5 mg/ml CEI (n = 21)	5 mg/ml PCEA (n = 20)	P	1.5 mg/ml P	5 mg/ml P
AUC (cm ²)	23.9 \pm 22.6	56.0 \pm 52.6	29.6 \pm 30.6	54.0 \pm 28.7	0.002	0.013	0.006
VAS _{max} (cm)	2.38 \pm 1.43	4.26 \pm 2.40	2.62 \pm 1.95	3.90 \pm 1.86	0.005	0.004	0.039
VAS _{mean} (cm)	0.53 \pm 0.50	1.24 \pm 1.09	0.63 \pm 0.64	1.31 \pm 0.76	0.002	0.012	0.003
PVAS > 3 (h)	1.21 \pm 3.61	5.95 \pm 10.4	1.57 \pm 3.36	4.26 \pm 4.82	0.050	0.060	0.044
Morphine 0–48 h (mg)	11.0 \pm 10.8	11.9 \pm 15.7	13.9 \pm 12.1	10.1 \pm 10.6	0.41	0.41	0.21
Propacetamol 0–48 h (g)	16 \pm 0	16 \pm 0	16 \pm 0	16 \pm 0	0.99	0.99	0.99
NSAIDs 0–48 h (n)	20 (100%)	17 (81%)	18 (86%)	15 (75%)	0.14	0.039	0.39
LB 24 h (mg)	360 \pm 0	104 \pm 54.3	360 \pm 0	106 \pm 53.5	< 0.001	< 0.001	< 0.001
LB 24–48 h (mg)	360 \pm 0	66 \pm 62	360 \pm 0	72 \pm 71	< 0.001	< 0.001	< 0.001
LB 0–48 h (mg)	720 \pm 0	170 \pm 103	720 \pm 0	182 \pm 110	< 0.001	< 0.001	< 0.001
Bromage (I/II/III) (n)	1/1/0	0/0/0	4/3/1	1/0/0	0.008	0.48	0.04
Anti-emetic 0–48 h (n)	4 (20%)	5 (24%)	2 (9%)	7 (35%)	0.27	0.77	0.049
Satisfaction (3/4) (n)	8/12	6/10	10/11	8/12	0.79	0.75	0.69

AUC, area under the visual analogue scale (VAS)-time curve; CEI, continuous epidural infusion; LB, levobupivacaine; NSAIDs, non-steroidal anti-inflammatory drugs; PCEA, patient-controlled epidural analgesia; PVAS > 3, persistence of VAS over 3 cm.

P, comparison between CEI and PCEA groups; P 1.5 mg/ml, comparison between the two 1.5 mg/ml groups; P 5 mg/ml, comparison between the two 5 mg/ml groups.

Our results on the relative effect of the concentration and volume of local anaesthetics are in accordance with previous studies (5, 7, 23–26). Duggan et al. (5) showed that the onset and recovery from surgical analgesia were similar with 7.5 and 5 mg/ml bupivacaine solutions when administered at the same dose. In the post-operative period, Laveaux et al. (23) compared the analgesic efficacy and side-effects of thoracic CEI using bupivacaine with sufentanil at high concentration/low volume vs. low concentration/high volume. They showed excellent analgesia and no difference in the incidence of side-effects in the two groups. These authors concluded that the total dose of the local anaesthetic was more important than the concentration or volume of the solution. Mogensen et al. (24) showed that pain relief and regression of analgesia were similar during CEI of either 8 ml/h of 5 mg/ml bupivacaine or 16 ml/h of 2.5 mg/ml bupivacaine. Similar results were reported by Scott et al. (25). Murdoch et al. (26) observed that levobupivacaine 2.5 mg/ml as CEI provided better post-operative analgesia without any significant increase in motor blockade when compared with a concentration of 1.25 mg/ml. Recently, Darnedde et al. (12, 13) have demonstrated that the same dose of opioid-free levobupivacaine provides an equal quality of analgesia in small- or large-volume CEI.

However, as mentioned in the introductory section, there are some discrepancies in the literature concerning the analgesic effects of large-concentration/small-volume local anaesthetics. After thoracic surgery, Snijdelaar et al. (27) found better analgesia with high-volume/low-concentration CEI of epidural local anaesthetics than with low-volume/high-concentration CEI. In their study, they used a smaller amount of bupivacaine, i.e. 7.5–10 mg/h, than the 15 mg/h used in our study. This could contribute to the higher incidence of pain at rest experienced by their patients. Liu et al. (14), using PCEA after lower abdominal surgery, observed that a lower concentration of a similar amount of epidural ropivacaine/fentanyl provided equal analgesia with less motor blockade when compared with higher concentrations of the local anaesthetic. However, they placed epidural catheters at the Th12–L2 interspaces. It has already been shown that the placement of catheters in proximity to the lumbar spinal segments increases the risk of motor block when compared with a more cephalad approach (2). Whiteside et al. (15), using the same combination of drugs after gynaecological surgery, showed that a low-concentration/high-volume

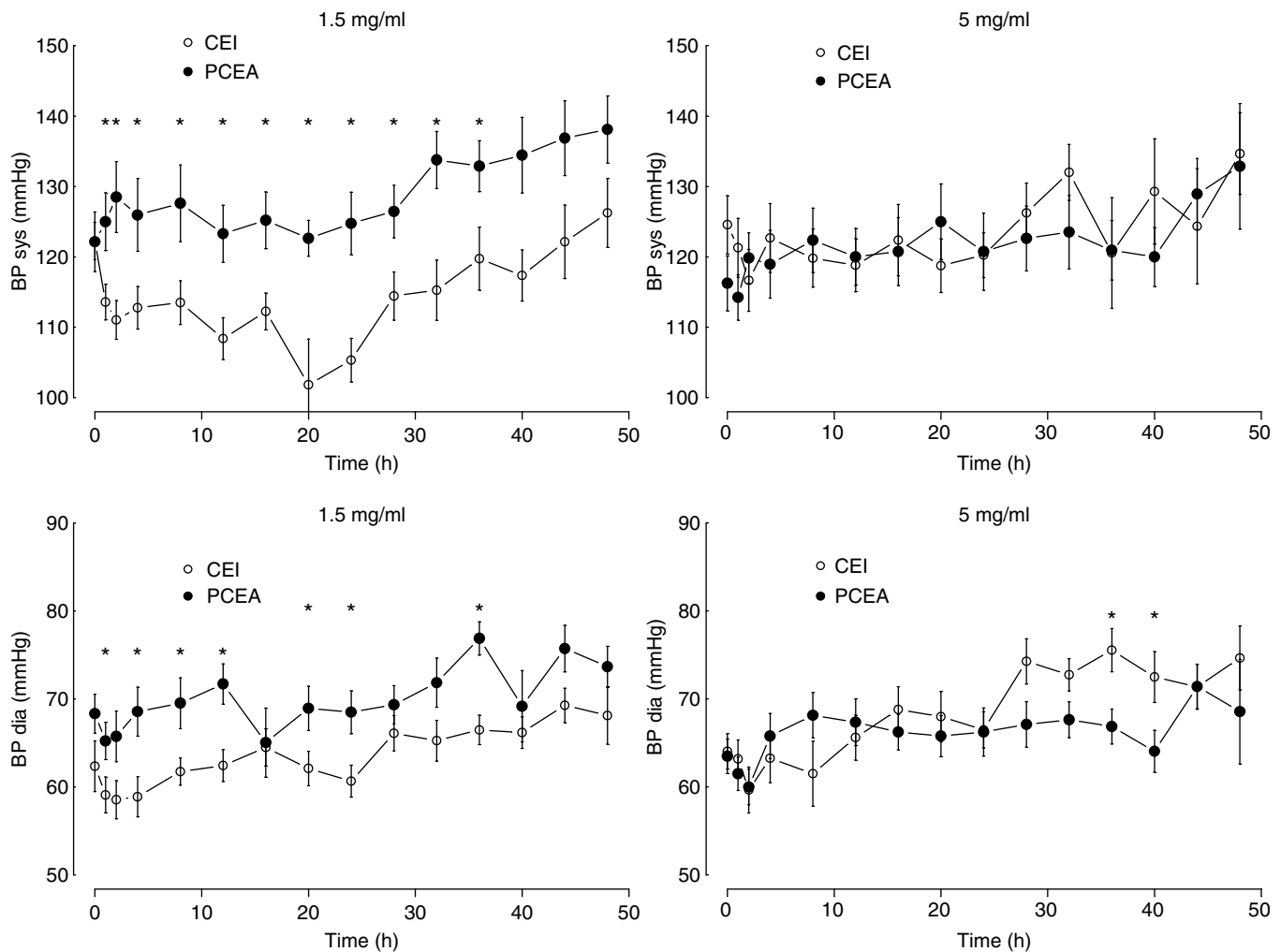


Fig. 3. Evolution of mean systolic (sys) and diastolic (dia) blood pressure (BP) in the four groups of patients during the 48-h study period. Concentration (1.5 and 5 mg/ml) refers to levobupivacaine. CEI, continuous epidural infusion; PCEA, patient-controlled epidural analgesia. Errors bars indicate standard deviation. Blood pressure was lower in the 1.5 mg/ml CEI group than in the 1.5 mg/ml PCEA group ($P = 0.036$; general linear model statistics). * $P < 0.05$ (Student's *t*-test).

PCEA appeared to be satisfactory for the treatment of post-operative pain and to decrease the dose of drugs used in comparison with a low-volume/high-concentration PCEA. Standl et al. (3) showed that PCEA using local anaesthetic plus sufentanil provided at least as good or even better post-operative pain relief than CEI with comparable side-effects.

Our study differs considerably from these previous experiments because we did not add any opioid epidurally and focused only on local anaesthetic action. Administration of a high volume of opioid associated with the local anaesthetic could produce more extensive sensory block as a result of greater anatomic spread and interaction with opiate receptors (2, 27). Opioids also limit the regression of the sensory block observed with local anaesthetics alone and improve the quality of pain

relief (28). This makes a comparison with our results difficult.

It is commonly stated that CEI using highly concentrated local anaesthetics can cause increasing motor weakness (3). We administered the local anaesthetics at a low thoracic level to maximise the analgesic effects in the thoracoabdominal somatosensory distribution, where motor effects are not clinically significant. In the PCEA groups, Bromage scores were zero at all time points with concentrations of 1.5 and 5 mg/ml. We observed higher motor blockade with the CEI delivery mode than with the PCEA mode, specifically in the 5 mg/ml group. In these patients, epidural catheters were inserted at a lower level (Th10-L1) than in the other groups, increasing the risk of motor blockade (2). Similarly, the cephalad

level of the sensory block was lower in the 5 mg/ml CEI group.

The cephalad extent of sensory block was more extensive in the 1.5 mg/ml CEI and 5 mg/ml PCEA groups, with no difference in the other two groups. Systolic and diastolic blood pressures were lower in the 1.5 mg/ml CEI group than in the 1.5 mg/ml PCEA group, indicating a relationship between sympathetic blockade and cephalad spread.

Previous reports have shown that an increase in epidural injected volume does not result in a linear increase in block height (5, 29, 30). Unfortunately, we did not assess the caudal spread of sensory block. When examining the different factors influencing the spread of the local anaesthetic, Simon et al. (31) showed that age influences the spread of the neural block, as well as the absorption and disposition of the local anaesthetic after epidural administration of levobupivacaine. The small number of patients included in this study did not enable us to reveal an effect of age on the upper level of analgesia in the elderly. Further study should also focus on the pharmacokinetics of levobupivacaine in the two modes of delivery, mainly in CEI.

In our study, we did not use background infusion in the PCEA groups. Numerous studies have supported the use of PCEA associated with background infusion (2, 32). Komatsu et al. (33) showed the advantages of the use of a PCEA background infusion employing a local anaesthetic and opioid mixture following upper abdominal surgery. These included a decreased incidence and degree of post-operative pain, without an increase in serious side-effects, partly supporting our results. Other data suggest that there is no advantage of adding a continuous infusion in PCEA because of an increase in the incidence of side-effects, i.e. nausea and vomiting, and motor blockade (34). It should be noted that, in the study of Wong et al. (34), using a combination of ropivacaine and fentanyl, epidural catheters were placed at the lumbar level (L2–L4), which could explain the higher occurrence of motor blockade. Nevertheless, the effect of concentration vs. volume of local anaesthetic in PCEA with background infusion should be evaluated.

Tachyphylaxis did not occur in any of the groups. Furthermore, in the PCEA group, levobupivacaine consumption decreased during the second day relative to the first 24 h. These results are in line with Lipfert's statement that tachyphylaxis is not linked to the mode of administration, i.e. intermittent vs. continuous (35).

The most important limitation related to the study design was that only rest pain was assessed. Further studies need to focus on pain during mobilisation or coughing. Nevertheless, the goal of totally pain-free patients regardless of movement may not be realistic with an epidural pain programme, as recently stated by Andersen et al. (36).

Finally, it may be interesting to evaluate the use of a high concentration of the local anaesthetic for thoracic epidural analgesia. The 5 mg/ml levobupivacaine solution is ready to use. This could result in fewer administration errors and decreased nursing time and pharmacy preparation costs. Furthermore, as CEI induces the same quality of pain relief as PCEA, there is no need for sophisticated, expensive infusion devices, such as PCEA pumps and disposables.

In conclusion, levobupivacaine provides an equal quality of post-operative analgesia in low or high volume and in the two delivery modes: thoracic CEI or PCEA. This is in accordance with the assumption that the total dose, and not the volume or concentration of the local anaesthetic, determines the quality of analgesia.

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